PATENT ABSTRACTS OF JAPAN

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HEISMANN FRED L
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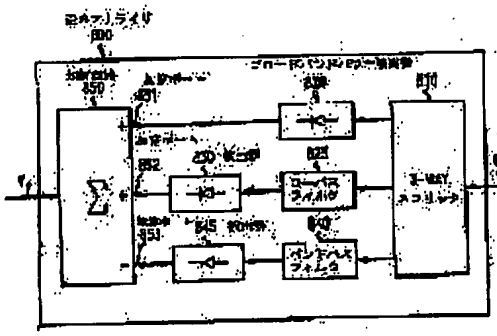
(30)Priority

Priority number : 1999 465152 Priority date : 16.12.1999 Priority country : US

(54) COMPENSATOR COMPENSATING POLARIZATION MODE DISPERSION OF OPTICAL FIBER



(57)Abstract:

PROBLEM TO BE SOLVED: To provide a compensator which compensates polarization mode dispersion.

SOLUTION: A receiver compensates the influence of the polarization dispersion on an optical signal during propagation in an optical fiber by using a birefringence compensator. A distortion analyzer inspects the signal outputted from the compensator, which operates based on the inspection result to reduce the influence of polarization compensation dispersion.

LEGAL STATUS

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CLAIMS

[Claim(s)]

[Claim 1] In the compensator (425) with which the effect of the polarization mode dispersion generated within the optical fiber (420) which has the main polarization condition is compensated (A) The polarization converter which orients again polarization of the specific component of an optical signal received through an optical fiber (420) (430), (B) Equipment to which it divides into two or more signals which have a polarization condition in the direction which intersects perpendicularly the output signal of said polarization converter with each condition of the two main polarization conditions, and adjustable carries out time delay of this divided signal (440, 485, 487), (C) The optical converter which changes into an electrical signal a part of signal outputted by the aforementioned (B) equipment (455), The distortion analyzer which has equipment which divides this changed signal into two or more signals (810), and gives this separated signal to the 1st, 2nd, and 3rd analyzer part (820, 825, 840), respectively, It ****. Said 1st analyzer part (820) The whole spectrum of an output signal is passed. Said 2nd analyzer part (825) A part of spectrum below a predetermined frequency is passed. Said 3rd analyzer part (840) Only the predetermined range of the whole spectrum is passed. The distortion analyzer (aforementioned [C]) Add the output of said 1st and 2nd analyzer part (851,852), and the output of the 3rd analyzer part is subtracted from said added value (853). A distortion indicator is generated and this distortion indicator (471) is given to said polarization converter (430) and division equipment (440) (aforementioned [B]). Said polarization converter and the aforementioned (B) equipment The compensator with which the polarization mode dispersion of the optical fiber characterized by changing the direction and said variable time of said polarization condition, respectively until the level of said distortion indicator reaches predetermined level according to change of the level of a distortion indicator is compensated.

[Claim 2] It is the compensator according to claim 1 which said 1st analyzer part has a

broadband power detector, and said 2nd analyzer part has the low pass filter connected to the broadband power detector at the serial, and is characterized by said 3rd analyzer part having the band pass filter connected to the broadband power detector at the serial.
[Claim 3] (D1) In order to generate a RF (AC) component and a low frequency (DC) component A means to process said part of the outputted signal, and in order to generate two or more (D2) signals A means to give said AC component to a splitter, and a means to supply DC component to a signal square means to square the value of DC (D3) component, (D4) The compensator according to claim 1 characterized by having further the receiver which has the means which carries out division of said subtracted value to it being also at the value of the signal by which the mean square was carried out, and a means to output the quotient of this (D5) division as a distortion indicator.
[Claim 4] In the compensator with which the effect of the polarization mode dispersion generated within the optical fiber which has the main polarization condition is compensated (A) The polarization converter which orients again polarization of the specific component of an optical signal received through an optical fiber, (B) Equipment in which divides into two or more signals which have a polarization condition in the direction which intersects perpendicularly with each condition of the two main polarization conditions the signal given to the output of said polarization converter, and adjustable carries out time delay to this divided signal, (C) The receiver which has the optical converter which changes into a predetermined signal a part of signal outputted by the equipment of the above (B), and generates AC component signal and DC component signal from this changed signal, Said receiver gives AC component signal to a distortion analyzer, and measures the level of first [at least] PMD distortion this distortion analyzer of whose is in AC component. Output the signal showing the level of this distortion and DC component is given to a signal square circuit. (D) A division means to give the signal of the quotient which carried out division and was obtained as a result on the level of the signal which squared the level of the signal showing said distortion to a polarization converter and the aforementioned (B) equipment as a distortion indicator, since -- said polarization converter and the aforementioned (B) equipment The compensator with which the polarization mode dispersion of the optical fiber characterized by changing the direction of said polarization condition and said variable time, respectively until the level of said distortion indicator reaches predetermined level according to change of the level of a distortion indicator is compensated.
[Claim 5] The distortion analyzer (aforementioned [C]) divides AC component ****** into two or more signals (810). This separated signal is given to the 1st, 2nd, and 3rd

analyzer part (820, 825, 840), respectively. Said 1st analyzer part (820) The whole spectrum of an output signal is passed. Said 2nd analyzer part (825) A part of spectrum below a predetermined frequency is passed. Said 3rd analyzer part (840) Only the predetermined range of the whole spectrum is passed. The distortion analyzer (aforementioned [C]) The compensator according to claim 4 characterized by adding the output of said 1st and 2nd analyzer part (851,852), subtracting the output of the 3rd analyzer part from said added value (853), and giving this subtraction result as a molecule of the division means (aforementioned [D]).

[Claim 6] It is the compensator according to claim 4 which said 1st analyzer part has a broadband power detector, and said 2nd analyzer part has the low pass filter connected to the broadband power detector at the serial, and is characterized by said 3rd analyzer part having the band pass filter connected to the broadband power detector at the serial.

[Claim 7] Said distortion analyzer divides AC component into two or more signals, and it has equipment which gives this divided signal to a part for a part for part I, and part II. The amount of said part I It has a blow band power detector. The amount of said part II It is the compensator according to claim 4 characterized by having the adder circuit which it has the low pass filter connected to the broadband power detector at the serial, and said distortion analyzer combines the output for a part for said part I, and part II further, and gives this combined signal to a division means.

[Claim 8] Said distortion indicator is a compensator according to claim 4 characterized by being feedback voltage.

[Claim 9] (A) The converting means which changes into an electrical signal the signal outputted by optical equipment, and divides this changed electrical signal into two or more signals, (B) the 1st, the 2nd and the 3rd partial analyzer which receive each one of said two or more signals, and said part I part analyzer The whole spectrum of the outputted signal is passed. Said part II part analyzer A part of spectrum below a predetermined frequency is passed. Said part III part analyzer Pass the predetermined range of the whole spectrum, add the output of the (C) above 1st and the 2nd partial analyzer, and the output of the part III part analyzer is subtracted from this added result. a means to generate a distortion indicator and to give this distortion indicator to optical equipment -- since -- the distortion analyzer characterized by becoming.

[Claim 10] (A) A conversion means to change into an electrical signal the signal outputted by optical equipment (455), (B) Change said electrical signal into AC component signal and DC component signal, and this AC component signal is divided into two or more signals. The receiver which divides this AC component signal into two or more signals, and gives this AC component signal to the part (1010) of each distortion

analyzer (1005), (C) Division is carried out to a square means (1020) to square the value of said DC component signal, by the signal which squared the signal outputted from the (D) aforementioned distortion analyzer. a division means (1030) to give the signal of the quotient obtained as a result to optical equipment as a distortion indicator -- since -- the optical equipment characterized by changing the level of the signal outputted until the distortion indicator reached the predetermined condition according to receipt of this distortion indicator.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the so-called processing of the polarization mode dispersion in such a system especially about optical communication system.

[0002]

[Description of the Prior Art] Polarization mode dispersion (Polarization Mode Dispersion:PMD) breaks out within an optical fiber owing to a small residual birefringence. This residual birefringence is introduced into incore [of a fiber] by random polarization association resulting from the external force concerning unsymmetrical internal stress and an unsymmetrical optical fiber. PMD has a bad influence on transmission of the signal in an optical fiber network. This is being able to say especially about the digital lightwave system of the present age which operates with the bit rate more than 10Gb/a second in the wavelength channel transmitted.

[0003] U.S. Pat. No. 5930414 (date of issue: 1999.7.27 and artificer:D.A.Fishman etal) is indicating the equipment which makes damage on the signal resulting from PMD ease. between the polarization conditions (namely, the main polarization condition, Principal States of Polarization:PSP) which this equipment has an adjustable optical birefringence element, and intersect perpendicularly with mutual [in a transmission fiber / at least two / selectable] by this -- difference -- optical time delay is introduced. The optical-strain analyzer connected to the output of an adjustable birefringence element is generating the control signal to this element.

[0004] difference continuously adjustable to between the two main polarization conditions in order that the compensator shown in drawing 4 of a patent shown above may compensate primary [in the fiber for transmission / PMD] -- group delay (Differential Group Delay:DGD) is generated. PSP of the adjustable birefringence

component with which one different point between the delay lines shown in drawing 1 of a patent of this equipment and the above-shown was shown in drawing 4 is a point with frequency dependent. Such frequency dependent (this is an important side face to the effect of secondary [so-called / PMD]) will introduce a superfluous distortion into an optical signal. The reason is that primary [in a fiber / PMD] is compensated only to a certain optical bandwidth, and PMD is because it still increases in a part with optical spectrum further again.

[0005] The signal distortion resulting from the effect of secondary [PMD] in the digital optical signal of the conventional non return two zero (non-return-to-zero:NRZ) and return two zero (return-to-zero:RZ) is observed as a "tone" of the narrowband of spectrum energy in the electric spectrum of a receiving optical signal in a certain frequency to a signal bit rate like 20GHz to 10GHz and RZ signal to an NRZ signal.

[0006]

[Problem(s) to be Solved by the Invention] Therefore, the purpose of this invention is offering the approach of canceling the signal distortion by PMD, and equipment.

[0007]

[Means for Solving the Problem] In order to decrease distortion caused by the effect of secondary [in the adjustable birefringence component of a PMD compensator / PMD] according to this invention, it is carried out by polarizing the control signal added to an adjustable birefringence component so that an optical signal may be influenced the fewest of secondary [PMD]. Especially the control signal generated by drawing 2 of a patent shown above or the distortion analyzer of 8 polarizes by removing the output signal of the band pass filter set by the tone of the narrowband outputted by the distortion analyzer by the approach of weighting from the control signal. The signal Vf which was acquired as a result and which polarized is added to the polarization controller in an adjustable birefringence component, and reduces the level of distortion which happens as a result of the effect of secondary PMD. It will operate by this Vf of ** that polarized in that the whole distortion of secondary [of both the fiber for transmission and a PMD compensator] serves as min, as for the compensator of PMD. Especially PSP of a compensator makes a secondary PMD distortion generated with the fiber for transmission offset according to the description of this invention. That is, the effect of secondary is removed rather than is added to distortion generated with the fiber for transmission.

[0008]

[Embodiment of the Invention] In this specification, the compensatory system indicated by U.S. Pat. No. 5930414 is mentioned as an example, and is explained.

[0009] Polarization mode dispersion (PMD) is generated in a single mode fiber as a result of association of the random polarization in various locations which met the residual birefringence and optical fiber of an optical fiber incore.
[0010] To optical frequency omega=omega 0, two polarization rectangular cross conditions called the main polarization condition (PSP) exist. The optical signal which spreads an optical fiber does not receive the big difference delay between difference minutes, when it is polarizing in the state of one side of the two PSPs.
[0011] difference -- group delay tauf occurs between two PSPs of a fiber. the difference which it wears as a result to which an optical signal spreads the inside of an optical fiber -- an amount with group delay (differential group delay:DGD) equal at the outputting point of an optical fiber -- and difference with an opposite sign -- it can compensate by introducing time delay tauc=-tauf. This can be easily performed by using the optical element which has the polarization property indicated by the patent shown above.
[0012] PMD in a fiber -- the passage of time -- or if an optical frequency changes, it will change. Including change of PSP and change tauf of DGD to which the change in PMD corresponds, this can be compensated by changing the amount and direction of a birefringence of [in a compensator], and, as a result, compensates DGD in a fiber automatically. An automatic adjustable birefringence compensator is realizable by arranging at a serial the polarization converter indicated by U.S. Pat. No: 5212743 (date of issue: 1993.5.18 and artificer:F.L.Heismann) for the component which generates adjustable linear birefringence. Such an adjustable birefringence divides the signal of the outputting point of a polarization transducer into two orthotomic form polarization conditions corresponding to two PSPs of an optical fiber, and when only variable time tauc delays one side of them using the delay line 50 (for example, JDS Fitel Inc polarization mode dispersion EMIRETA, Model PE 3 which are marketed from the shrine) of drawing 1 of a patent shown above, it can attain it.
[0013] The option which makes such a birefringence generate is shown in drawing 1 . This example generates the fixed delay tau1 and tau2 between difference minutes including the almost same 1st light birefringence fiber 435 and the 2nd light birefringence fiber 445 between the optical signals with which these intersected perpendicularly in accordance with the low-speed optical axis and the high-speed optical axis of two fibers. the 1st light birefringence fiber 435 and the 2nd light birefringence fiber 445 -- Fujikura Co., from -- it is SM15-P-8/125 marketed, and has the time delay of 1.4 ps/m. Therefore, the 2nd automatic polarization transducer 440 inserted between the 1st light birefringence fiber 435 and the 2nd light birefringence

fiber 445 controls include-angle thetac between the high-speed shafts of the 1st light birefringence fiber 435 and the 2nd light birefringence fiber 445. Difference minute delay tauc generated with the 1st light birefringence fiber 435 and the 2nd light birefringence fiber 445 is expressed with a degree type.

[Equation 1]

$$\tau_c = \sqrt{\tau_1^2 + \tau_2^2 + 2\tau_1\tau_2\cos(2\theta_2)}$$

This changes continuously between the minimum value of |tau1-tau2|, and the maximum of (tau1+tau2).

[0014] the difference generated with the polarization conversion performed within the 1st automatic polarization transducer 430, and the 1st light birefringence fiber 435 and the 2nd light birefringence fiber 445 -- the difference which will generate within the optical fiber 420 for transmission to the signal outputted by the compensator 425 if the 1st automatic polarization transducer 430 is suitably adjusted by the approach indicated by the patent shown above with time delay -- distortion caused by group delay is lost.

[0015] the adjustable difference generated using a feedback signal with the polarization conversion in the 1st automatic polarization transducer 430 (namely, the direction of an adjustable birefringence), and the 1st light birefringence fiber 435 and the 2nd light birefringence fiber 445 -- the 2nd automatic polarization transducer 440 is controlled with time delay. A desired feedback signal is generated at the outputting point of a compensator 425 by supervising the amount of PASURU distortion. After this pulse distortion spreads the inside of a compensator 425, it is caused by the delay between difference minutes which exists in an optical signal.

[0016] in order that only one feedback signal 471 may attain the minimum distortion in the signal which a compensator 425 outputs to the optical receiver 490 through the conventional optical tap 485 -- polarization conversion and difference -- it is required to adjust delay tauc to coincidence.

[0017] If it explains concretely, a part of signal which a compensator 425 outputs will be given to pass 487 through the optical tap 485. This pass 487 is extended to the high-speed photodetector 455. This high-speed photodetector 455 is Hewlett Packard Co., model 11982 Wideband Lightwave Converter of a shrine It has an electric bandwidth equal to the information bandwidth of the modulation optical signal transmitted by the optical transmitter 410 at least. The remaining signal is given to the pass 486 extended to the optical receiver 490. The high-speed photodetector 455

changes into an electrical signal the high-speed digital information signal modulated on the optical carrier signal. This electrical signal is amplified by amplifier 460, measures the distortion within the photocurrent by which it was combined with the electrostriction analyzer 470 and this electrostriction analyzer 470 was amplified, and changes it into the electrical potential difference Vf to which this amplified result is given to the electrostriction analyzer 470. And this is proportional to distortion. for example, an electrical potential difference Vf reaches maximum, when it does not have distortion to which an optical signal originates in primary [PMD] (namely, association of the optical fiber 420 for transmission, and a compensator 425 -- difference -- time delay is almost equal to zero).

[0018] When DGD in the fiber for transmission is restricted to the value below maximum (taumax), the distortion within an optical signal can be measured only by measuring the amplitude of the received electrical signal of specific frequency F<1/(2taumax). The direction and level of DGD which were generated in the compensator 425 so that a feedback signal might serve as max are adjusted automatically, using the amplitude of this signal as a feedback signal.

[0019] the total inserted into a transmission system -- the above-mentioned requirements setup max to DGD, i.e., tau total<tau, restricts amount tauf of DGD compensated within the fiber for optical transmission as tautotal<2tauf. for example, a 10Gbps digital transmission system -- if it is, the amplitude of a received electrical signal must be measured by 5GHz, and tauf must always be lower than 50ps(es). Otherwise, it becomes indefinite at a difficult point to determine that it is necessary to adjust the feedback signal generated as a function of the amplitude of a 5GHz component so that amount [of polarization conversion], direction, and difference minute delay tauc may obtain tautatal=0. To a different value whose amplitude of a feedback signal is two of tautotal(s), when the same, it will generate, and this will adjust this accidentally [direction / of delay between difference minutes / of / in a compensator 425 / the level and the direction].

[0020] The feedback signal (namely, signal which is the only measured value of tautotal) "which is not not clear" is generated by measuring the amplitude of two or more frequency components contained in the optical information signal which spreads the inside of an optical fiber, without restricting the level of compensation added to DGD. An example of a compensator which analyzes almost all the amplitude of the electric frequency spectrum which received using the broadband power detector is shown in drawing 1 . The broadband power detector 495 is Hewlett Packard Co., model 8474 marketed from the shrine It is a diode detector, and such amplitude is changed into the

single feedback voltage Vf, and this Vf is proportional to the integral value of the amplitude (power level) of high frequency electrical-and-electric-equipment spectrum.
[0021] the compensator shown in drawing 1 -- continuously adjustable difference -- group delay (DGD) is generated and primary DGD is compensated. The point of differing between the delay lines between difference minutes shown in drawing 1 of a patent of this compensator and the above-shown is a point which shows the main polarization condition (PSP) that the compensation part formed with the 1st light birefringence fiber 435 and the 2nd light birefringence fiber 445 and the 2nd automatic polarization converter 440 of drawing 1 change a lot with an optical frequency. Such frequency dependent (this is one side face of the effect of secondary [so-called / PMD]) makes the optical signal in a compensator distorted. It is because DGD which receives the reason within a fiber is removable only in a certain optical frequency range. DGD may increase in a part with spectrum further again.
[0022] Next, to the conventional on-the-strength strange modulated light study signal, to the digital signal by which formatting was carried out by non return TUZERO (NRZ), the effects of secondary PMD are 10Gb/a second, and they are about 10GHz, and when the "tone" of the narrowband of the spectrum energy in the frequency to which the signal bit rate of 20GHz is equivalent to the signal by which formatting was carried out by 10Gb/return TUZERO of a second appears, they are observed in an electric field. In this way, distortion caused by the effect of secondary PMD can observe a distortion analyzer as drawing 2 of a patent of the above-shown which polarized according to the bandpass property of the frequency of a bit rate, and the frequency selective device of the class shown in 8 are also.
[0023] The effect of distortion which lengthens by secondary [PMD] and is exceeded can be processed by subtracting the output of the band pass filter aligned with the tone of a narrowband by the approach of weighting from the signal outputted by the distortion analyzer of drawing 2 of this specification. The signal Vf which was acquired as a result and which polarized is given to a compensator, and the level of distortion which carries out the result of the effect of secondary [PMD], and is generated is reduced. If it explains still more concretely, it will depend for a compensator on the point (dither) of setting a core to the field of the exact adjustment of DGD and PSP in the spectrum field of the maximum distortion within an optical signal, by Vf which polarized. Thereby, the effect of secondary [PMD] can be reduced. It does not add to a distortion secondary [PMD] in which secondary [which was generated in the compensator / PMD] receives a distortion secondary [PMD] in which a signal receives PSP of a compensator within the fiber for transmission by the improvement by this

invention within the fiber for transmission, but is offset towards subtracting.
[0024] Drawing 3 shows the distortion analyzer which polarized by this invention, and this distortion analyzer generates the control signal Vf changed into the amplifier 460 which gives the amplified electrical signal to a distortion analyzer. The conventional 3 direction splitter 810 divides the amplified signal into three signals, and gives each to the broadband power detector 820, a low pass filter 825, and a band pass filter 840. The broadband power detector 820 gives a signal (voltage level proportional to the power of the whole frequency spectrum of a signal) as usual to the addition port 851 of the conventional adder circuit 850. On the other hand, a low pass filter 825 carries out filtering of the electrical signal, and makes a detector 830 pass a part of frequency spectrum and 2.5GHz or less of ********. The signal from a detector 830 is given to the low pass filter 825 of an adder circuit 850. Furthermore, a band pass filter 840 carries out filtering of the signal received from the 3 direction splitter 810, and passes only the 1GHz signal centering on 10GHz predetermined spectrum within the limits of a signal. The signal outputted from the band pass filter 840 is given to the subtraction port 853 of an adder circuit 850 through a detector 845. An adder circuit 850 subtracts the signal received through the subtraction port 853 from the sum of a signal which received through the addition port 851 and the addition port 852 as usual. In this way, a distortion analyzer outputs a feedback signal Vf and this Vf cooperates negatively the spectrum around the predetermined spectrum of a signal (for example, a 10GHz perimeter) (in the direction of minus). In order to delete with the frequency tone which a compensator 425, for example, the compensator of drawing 1 , generates as a result of the effect of secondary [PMD] by such coordination, it applies by the DIZADO approach.
[0025] The feedback voltage VF shown in the patent (9) type shown above and the feedback voltage Vf which was generated by the distortion analyzer of drawing 3 of this specification and which polarized are reduced when the polarization dependency loss (polarization-dependent loss:PDL) generated in the compensator 425 (for example, polarization converter) exists. this feedback voltage Vf is proportional to the square of all the optical power that was taken from a RF to low frequency namely, the radio frequency (RF) from light -- from two steps of root-squaring-methods rule (two stages of square-law detection) detection, therefore received. By carrying out division of the feedback signal by the square of the average optical power which the high-speed photodetector 455 received, the bad influence of loss of the polarization dependency in a compensator 425 can be reduced, therefore PMD compensation of higher level can be performed.
[0026] According to this invention, such exact control is performed by the circuitry

shown in drawing 4 , and the electrical signal to which the frequency splitter 1005 was outputted by the high-speed photodetector 455 as usual is divided into a RF (AC) component and a low frequency (DC) component in this circuitry. According to one example of this invention, the frequency splitter 1005 is formed from one or two or more conventional transimpedance LC circuits. A high frequency component is supplied to the distortion analyzer 1010 after optical magnification including the information relevant to the distortion within a high-speed digital signal (this is either drawing 2 or the distortion analyzer of 3). A low frequency (DC) component has the level proportional to the average value of the optical power which received, and this is given to the conventional square circuit 1020. In one example of this invention, the square circuit 1020 is an analog multiplier which has two inputs connected mutually. The signal of the outputting point of the square circuit 1020 is given after that to the denominator terminal (D) of the conventional ratio circuit 1030. The feedback voltage Vf0 from the distortion analyzer 1010 is given to the molecule terminal (N) of a ratio circuit 1030. This division result is given to the outputting point of a ratio circuit 1030 as a feedback signal Vf. This Vf is normalized by receiving optical power and removes the effect of the optical power fluctuation resulting from PDL.

[0027] The reduction of the effect of polarization-dependent loss which is generated within a compensator 425 and which is not desirable, and reduction of the dynamic range for which the control circuit of an automatic polarization transducer is needed are one of the advantages of this invention.

[0028] Based on the above-mentioned explanation, this contractor can process the effect of still higher order PMD by making it include further the part and polarization converter of a fiber of a high birefringence for a compensator like a compensator 425 if needed.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The block diagram which expresses a system conventionally to which this invention is applied.

[Drawing 2] The block diagram of another distortion analyzer used in order to take out a feedback signal to the PMD compensators of drawing 1 .

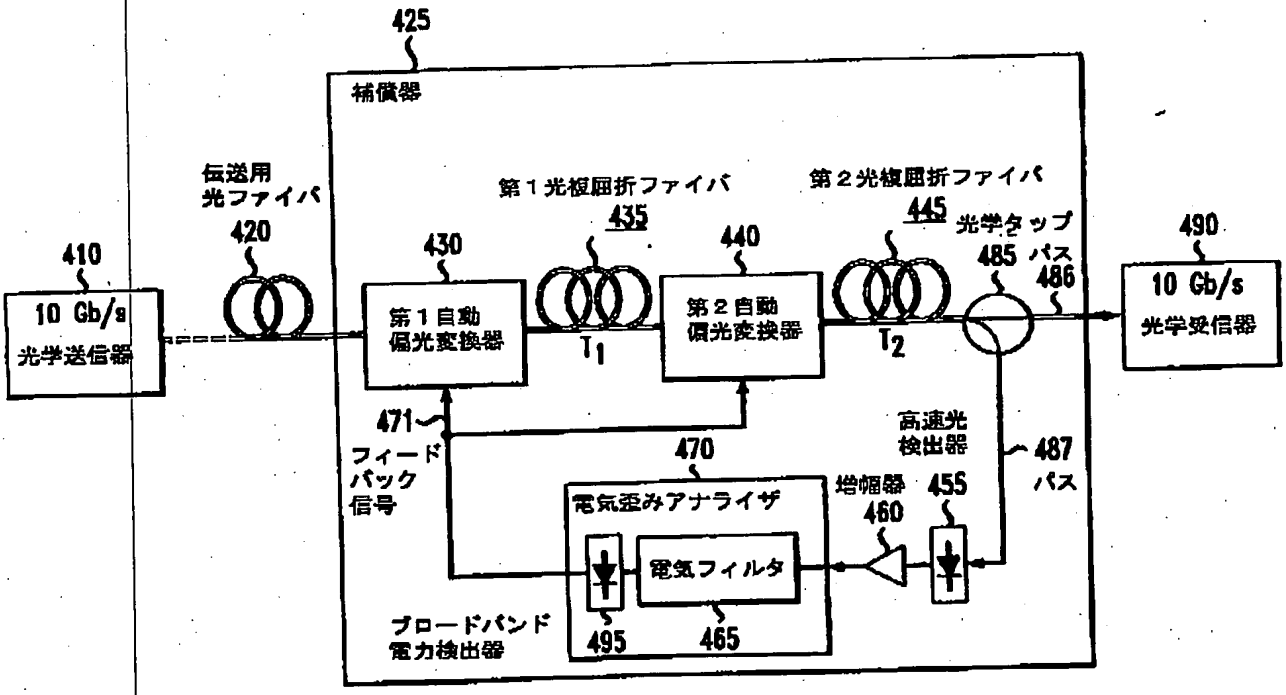
[Drawing 3] The block diagram showing other examples of a distortion analyzer furthermore improved.

[Drawing 4] The block diagram showing other examples of a distortion analyzer furthermore improved.

[Description of Notations]
410 Optical Transmitter
420 Optical Fiber for Transmission
425 Compensator
430 1st Automatic Polarization Converter
440 2nd Automatic Polarization Converter
435 1st Light Birefringence Fiber
445 2nd Light Birefringence Fiber
455 High-speed Photodetector
460 Amplifier
465 Electrical Filter
470 Electrostriction Analyzer
471 Feedback Signal
485 Optical Tap
486 487 Pass
490 Optical Receiver
495 Broadband Power Detector
800 Distortion Analyzer
810 The 3 Direction Splitter
820 Broadband Power Detector
825 Low Pass Filter
830 845 Detector
840 Band Pass Filter
850 Adder Circuit
851 852 Addition port
853 Subtraction Port
1005 Frequency Splitter
1010 Distortion Analyzer
1020 Square Circuit
1030 Ratio Circuit

DRAWINGS

[Drawing 1]



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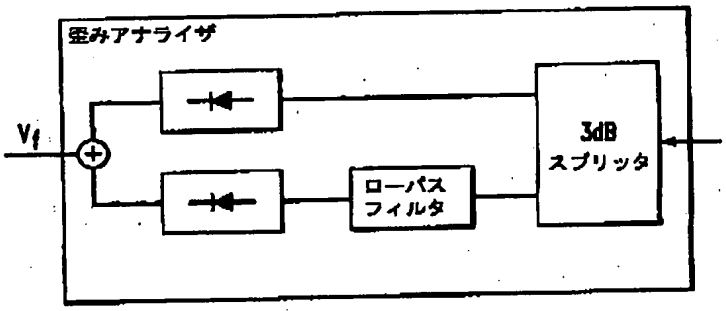

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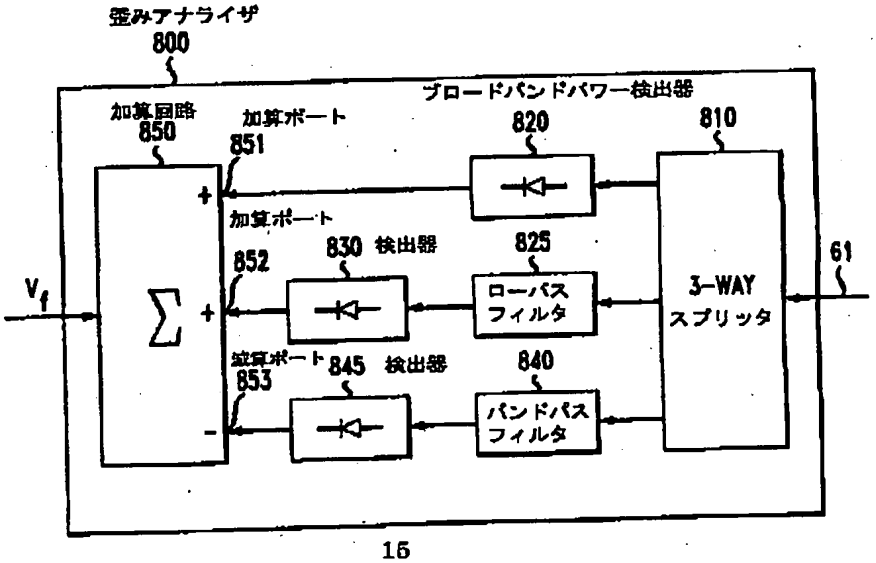

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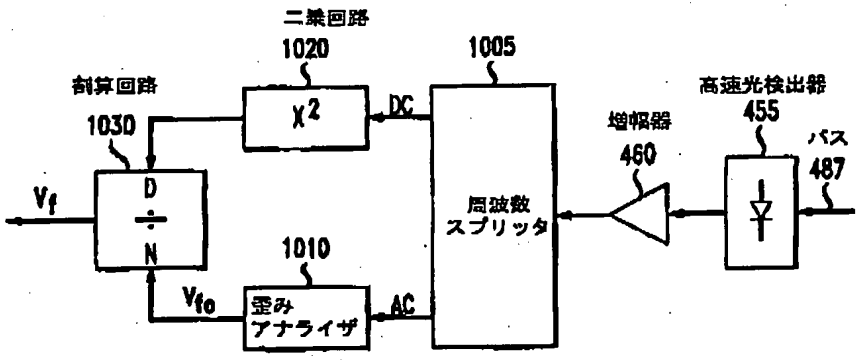

[Translation done.]

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CORRECTION OR AMENDMENT

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[FI]
H04B 9/00 M

[Procedure revision]
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[Procedure amendment 1]
[Document to be Amended] Specification
[Item(s) to be Amended] Claim
[Method of Amendment] Modification
[The contents of amendment]
[Claim(s)]
[Claim 1]
In the compensator (425) with which the effect of the polarization mode dispersion generated within the optical fiber (420) which has the main polarization condition is

compensated,

(A) The polarization converter which orients again polarization of the specific component of an optical signal received through an optical fiber (420) (430),

(B) Divide into a predetermined number of signals which have a polarization condition in the direction which intersects perpendicularly the output signal of said polarization converter with each condition of the two main polarization conditions, and they are adjustable time amount and equipment (440, 485, 487) to delay about this divided signal,

(C) The distortion analyzer which has the optical converter (455) which changes into an electrical signal a part of signal outputted by the aforementioned (B) equipment, and equipment which divides this changed signal into two or more signals (810), and gives this separated signal to the 1st, 2nd, and 3rd analyzer part (820, 825, 840), respectively,

It ****,

Said 1st analyzer part (820) passes the whole spectrum of an output signal,

Said 2nd analyzer part (825) passes a part of spectrum below a predetermined frequency,

Said 3rd analyzer part (840) passes only the predetermined range of the whole spectrum,

The distortion analyzer (aforementioned [C]) adds the output of said 1st and 2nd analyzer part (851,852), subtracts the output of the 3rd analyzer part from said added value (853), a distortion indicator is generated, and this distortion indicator (471) is given to said polarization converter (430) and division equipment (440) (aforementioned [B]),

Said polarization transducer and the aforementioned (B) equipment change the direction and said variable time of said polarization condition, respectively until the level of said distortion indicator reaches predetermined level according to change of the level of a distortion indicator.

The compensator with which the polarization mode dispersion of the optical fiber characterized by things is compensated.

[Claim 2]

In the compensator with which the effect of the polarization mode dispersion generated within the optical fiber which has the main polarization condition is compensated,

(A) The polarization converter which orients again polarization of the specific component of an optical signal received through an optical fiber,

(B) Divide into two or more signals which have a polarization condition in the direction which intersects perpendicularly with each condition of the two main polarization conditions the signal given to the output of said polarization converter, and they are adjustable time amount and equipment to delay about this divided signal,

(C) Change into a predetermined signal a part of signal outputted by the equipment of the above (B), and it consists of a receiver which has the optical converter which generates AC component signal and DC component signal from this changed signal,
Said receiver gives AC component signal to a distortion analyzer, the level of primary PMD distortion is measured at least, and this distortion analyzer outputs the signal showing the level of this distortion in AC component, it gives DC component to a signal square circuit, and is said compensator further,
(D) A division means to give the signal of the quotient which carried out division and was obtained as a result on the level of the signal which squared the level of the signal showing said distortion to a polarization converter and the aforementioned (B) equipment as a distortion indicator,
since
Said polarization transducer and the aforementioned (B) equipment change the direction of said polarization condition, and said variable time, respectively until the level of said distortion indicator reaches predetermined level according to change of the level of a distortion indicator.
The compensator with which the polarization mode dispersion of the optical fiber characterized by things is compensated.
[Claim 3]
In the compensator (425) with which the effect of the polarization mode dispersion generated within the optical fiber (420) which has the main polarization condition is compensated,
(A) The polarization converter which orients again polarization of the specific component of an optical signal received through an optical fiber (420) (430),
(B) The adjustable birefringence component to which it divides into a predetermined number of signals which have a polarization condition in the direction which intersects perpendicularly the output signal of said polarization converter with each condition of the two main polarization conditions, and adjustable carries out time delay of this divided signal (440, 485, 487),
(C) The distortion analyzer which has the high-speed photodetector (455) which changes into an electrical signal a part of signal outputted with the adjustable birefringence component (aforementioned [B]), and equipment which divides this changed signal into two or more signals (810), and gives this separated signal to the 1st, 2nd, and 3rd analyzer part (820, 825, 840), respectively,
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Said 1st analyzer part (820) passes the whole spectrum of an output signal,

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Said 3rd analyzer part (840) passes only the predetermined range of the whole spectrum,
The distortion analyzer (aforementioned [C]) adds the output of said 1st and 2nd analyzer part (851,852), subtracts the output of the 3rd analyzer part from said added value (853), a distortion indicator is generated, and this distortion indicator (471) is given to said polarization converter (430) and adjustable birefringence component (440) (aforementioned [B]),
Said polarization transducer and the adjustable birefringence component (aforementioned [B]) change the direction and said variable time of said polarization condition, respectively until the level of said distortion indicator reaches predetermined level according to change of the level of a distortion indicator.
The compensator with which the polarization mode dispersion of the optical fiber characterized by things is compensated.

[Claim 4]

Said 1st analyzer part has a broadband power detector,
Said 2nd analyzer part has the low pass filter connected to the broadband power detector at the serial,
Said 3rd analyzer part has the band pass filter connected to the broadband power detector at the serial.
The compensator according to claim 3 characterized by things.

[Claim 5]

In order to generate a RF (AC) component and a low frequency (DC) component, it is the frequency splitter which processes said part of the outputted signal,
In order that said splitter may generate two or more signals, said AC component is given to said splitter,
Said splitter which supplies said DC component to a signal square means to square the value of said DC component,
It is the division means which carries out division of said subtracted value to it being also at the value of the squared signal,
Said division means to output the quotient of this division as said distortion indicator
The compensator according to claim 3 characterized by having in a pan.

[Claim 6]

Said adjustable birefringence component is a compensator according to claim 3 which consists of the 2nd polarization converter constituted between two birefringence fibers.

[Claim 7]

In the compensator with which the effect of the polarization mode dispersion generated

within the optical fiber which has the main polarization condition is compensated,
(A) The polarization converter which orients again polarization of the specific component of an optical signal received through an optical fiber,
(B) Divide into two or more signals which have a polarization condition in the direction which intersects perpendicularly with each condition of the two main polarization conditions the signal given to the output of said polarization converter, and they are time amount adjustable to this divided signal, and the adjustable birefringence component to delay,
(C) The high-speed photodetector which changes into an electrical signal a part of signal outputted with the adjustable birefringence component (aforementioned [B]) (455),
(D) It is the frequency splitter which changes into a predetermined signal a part of signal outputted by the equipment of the above (C), and generates AC component signal and DC component signal from this changed signal,
Said frequency splitter is said frequency splitter which gives AC component signal to a distortion analyzer, and the level of primary PMD distortion is measured at least, and this distortion analyzer outputs the signal showing the level of this distortion in AC component, and gives DC component to a signal square circuit,
(E) A division means to give the signal of the quotient which carried out division and was obtained as a result on the level of the signal which squared the level of the signal showing said distortion to a polarization converter and the adjustable birefringence component (aforementioned [C]) as a distortion indicator,
since
Said polarization transducer and the adjustable birefringence component (aforementioned [C]) change the direction of said polarization condition, and said variable time, respectively until the level of said distortion indicator reaches predetermined level according to change of the level of a distortion indicator.
The compensator with which the polarization mode dispersion of the optical fiber characterized by things is compensated.
[Claim 8]
The distortion analyzer (aforementioned [D]) divides AC component signal into two or more signals (810), and gives this separated signal to the 1st, 2nd, and 3rd analyzer part (820, 825, 840), respectively,
Said 1st analyzer part (820) passes the whole spectrum of an output signal,
Said 2nd analyzer part (825) passes a part of spectrum below a predetermined frequency,
Said 3rd analyzer part (840) passes only the predetermined range of the whole spectrum,
The distortion analyzer (aforementioned [D]) adds the output of said 1st and 2nd

analyzer part (851,852), subtracts the output of the 3rd analyzer part from said added value (853), and gives this subtraction result as a molecule of the division means (aforementioned [E]).
The compensator according to claim 7 characterized by things.
[Claim 9]
Said distortion analyzer divides AC component into two or more signals, and it has the splitter which gives this divided signal to a part for a part for part I, and part II,
The amount of said part I has a blow band power detector,
The amount of said part II has the low pass filter connected to the broadband power detector at the serial,
Further, said distortion analyzer combines the output for a part for said part I, and part II, and has the adder circuit which gives this combined signal to a division means.
The compensator according to claim 7 characterized by things.
[Claim 10]
Said distortion indicator is feedback voltage.
The compensator according to claim 7 characterized by things.

[Translation done.]

< Second Amendment > 1/7

CORRECTION OR AMENDMENT

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compensated,
(A) The polarization converter which orients again polarization of the specific component of an optical signal received through an optical fiber (420) (430),
(B) Divide into a predetermined number of signals which have a polarization condition in the direction which intersects perpendicularly the output signal of said polarization converter with each condition of the two main polarization conditions, and they are adjustable time amount and equipment (440, 485, 487) to delay about this divided signal,
(C) The distortion analyzer which has the optical converter (455) which changes into an electrical signal a part of signal outputted by the aforementioned (B) equipment, and equipment which divides this changed signal into two or more signals (810), and gives this separated signal to the 1st, 2nd, and 3rd analyzer part (820, 825, 840), respectively,
It ****,
Said 1st analyzer part (820) passes the whole spectrum of an output signal,
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Said 3rd analyzer part (840) passes only the predetermined range of the whole spectrum,
The distortion analyzer (aforementioned [C]) adds the output of said 1st and 2nd analyzer part (851,852), subtracts the output of the 3rd analyzer part from said added value (853), a distortion indicator is generated, and this distortion indicator (471) is given to said polarization converter (430) and division equipment (440) (aforementioned [B]),
Said polarization transducer and the aforementioned (B) equipment change the direction and said variable time of said polarization condition, respectively until the level of said distortion indicator reaches predetermined level according to change of the level of a distortion indicator.
The compensator with which the polarization mode dispersion of the optical fiber characterized by things is compensated.
[Claim 2]
In the compensator with which the effect of the polarization mode dispersion generated within the optical fiber which has the main polarization condition is compensated,
(A) The polarization converter which orients again polarization of the specific component of an optical signal received through an optical fiber,
(B) Divide into two or more signals which have a polarization condition in the direction which intersects perpendicularly with each condition of the two main polarization conditions the signal given to the output of said polarization converter, and they are adjustable time amount and equipment to delay about this divided signal,

(C) Change into a predetermined signal a part of signal outputted by the equipment of the above (B), and it consists of a receiver which has the optical converter which generates AC component signal and DC component signal from this changed signal,
Said receiver gives AC component signal to a distortion analyzer, the level of primary PMD distortion is measured at least, and this distortion analyzer outputs the signal showing the level of this distortion in AC component, it gives DC component to a signal square circuit, and is said compensator further,
(D) A division means to give the signal of the quotient which carried out division and was obtained as a result on the level of the signal which squared the level of the signal showing said distortion to a polarization converter and the aforementioned (B) equipment as a distortion indicator,
since
Said polarization transducer and the aforementioned (B) equipment change the direction of said polarization condition, and said variable time, respectively until the level of said distortion indicator reaches predetermined level according to change of the level of a distortion indicator.
The compensator with which the polarization mode dispersion of the optical fiber characterized by things is compensated.
[Claim 3]
In the compensator (425) with which the effect of the polarization mode dispersion generated within the optical fiber (420) which has the main polarization condition is compensated,
(A) The polarization converter which orients again polarization of the specific component of an optical signal received through an optical fiber (420) (430),
(B) The adjustable birefringence component to which it divides into a predetermined number of signals which have a polarization condition in the direction which intersects perpendicularly the output signal of said polarization converter with each condition of the two main polarization conditions, and adjustable carries out time delay of this divided signal (440, 485, 487),
(C) The distortion analyzer which has the high-speed photodetector (455) which changes into an electrical signal a part of signal outputted with the adjustable birefringence component (aforementioned [B]), and equipment which divides this changed signal into two or more signals (810), and gives this separated signal to the 1st, 2nd, and 3rd analyzer part (820, 825, 840), respectively,
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Said 1st analyzer part (820) passes the whole spectrum of an output signal,

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The distortion analyzer (aforementioned [C]) adds the output of said 1st and 2nd analyzer part (851,852), subtracts the output of the 3rd analyzer part from said added value (853), a distortion indicator is generated, and this distortion indicator (471) is given to said polarization converter (430) and adjustable birefringence component (440) (aforementioned [B]),
Said polarization transducer and the adjustable birefringence component (aforementioned [B]) change the direction and said variable time of said polarization condition, respectively until the level of said distortion indicator reaches predetermined level according to change of the level of a distortion indicator.
The compensator with which the polarization mode dispersion of the optical fiber characterized by things is compensated.

[Claim 4]

Said 1st analyzer part has a broadband power detector,
Said 2nd analyzer part has the low pass filter connected to the broadband power detector at the serial,
Said 3rd analyzer part has the band pass filter connected to the broadband power detector at the serial.
The compensator according to claim 3 characterized by things.

[Claim 5]

In order to generate a RF (AC) component and a low frequency (DC) component, it is the frequency splitter which processes said part of the outputted signal,
In order that said splitter may generate two or more signals, said AC component is given to said splitter,
Said splitter which supplies said DC component to a signal square means to square the value of said DC component,
It is a division means as it is also at the value of the signal which squared said subtracted value,
Said division means which carries out division process to output the quotient of this division as said distortion indicator
The compensator according to claim 3 characterized by having in a pan.

[Claim 6]

Said adjustable birefringence component is a compensator according to claim 3 which consists of the 2nd polarization converter constituted between two birefringence fibers.

[Claim 7]

In the compensator with which the effect of the polarization mode dispersion generated within the optical fiber which has the main polarization condition is compensated,
(A) The polarization converter which orients again polarization of the specific component of an optical signal received through an optical fiber,
(B) Divide into two or more signals which have a polarization condition in the direction which intersects perpendicularly with each condition of the two main polarization conditions the signal given to the output of said polarization converter, and they are time amount adjustable to this divided signal, and the adjustable birefringence component to delay,
(C) The high-speed photodetector which changes into an electrical signal a part of signal outputted with the adjustable birefringence component (aforementioned [B]) (455),
(D) It is the frequency splitter which changes into a predetermined signal a part of signal outputted by the equipment of the above (C), and generates AC component signal and DC component signal from this changed signal,
Said frequency splitter is said frequency splitter which gives AC component signal to a distortion analyzer, and the level of primary PMD distortion is measured at least, and this distortion analyzer outputs the signal showing the level of this distortion in AC component, and gives DC component to a signal square circuit,
(E) A division means to give the signal of the quotient which carried out division and was obtained as a result on the level of the signal which squared the level of the signal showing said distortion to a polarization converter and the adjustable birefringence component (aforementioned [C]) as a distortion indicator,
since
Said polarization transducer and the adjustable birefringence component (aforementioned [C]) change the direction of said polarization condition, and said variable time, respectively until the level of said distortion indicator reaches predetermined level according to change of the level of a distortion indicator.
The compensator with which the polarization mode dispersion of the optical fiber characterized by things is compensated.
[Claim 8]
The distortion analyzer (aforementioned [D]) divides AC component signal into two or more signals (810), and gives this separated signal to the 1st, 2nd, and 3rd analyzer part (820, 825, 840), respectively,
Said 1st analyzer part (820) passes the whole spectrum of an output signal,
Said 2nd analyzer part (825) passes a part of spectrum below a predetermined frequency,
Said 3rd analyzer part (840) passes only the predetermined range of the whole spectrum,

The distortion analyzer (aforementioned [D]) adds the output of said 1st and 2nd analyzer part (851,852), subtracts the output of the 3rd analyzer part from said added value (853), and gives this subtraction result as a molecule of the division means (aforementioned [E]).
The compensator according to claim 7 characterized by things.
[Claim 9]
Said distortion analyzer divides AC component into two or more signals, and it has the splitter which gives this divided signal to a part for a part for part I, and part II,
The amount of said part I has a blow band power detector,
The amount of said part II has the low pass filter connected to the broadband power detector at the serial,
Further, said distortion analyzer combines the output for a part for said part I, and part II, and has the adder circuit which gives this combined signal to a division means.
The compensator according to claim 7 characterized by things.
[Claim 10]
Said distortion indicator is feedback voltage.
The compensator according to claim 7 characterized by things.
[Claim 11]
It is a distortion analyzer,
The splitter which divides an input signal into at least three division signals,
It is the part of at least three analyzers, and each analyzer part receives one of said the divided signals,
The analyzer part which generates the output signal corresponding to a part of spectrum of said division signal at least,
The adder circuit which processes said output signal from said at least three analyzer parts, and generates the distortion signal corresponding to said distortion in said input signal
** -- since -- the becoming distortion analyzer.
[Claim 12]
It is circuitry,
A frequency splitter which processes an input signal and produces high frequency (AC) and a low frequency (DC) component,
A distortion analyzer which generates the output signal which receives said AC component and supports the distortion in said AC component,
A square circuit which receives said DC component and generates the output signal corresponding to the square of said DC component,

Division of said output signal from said distortion analyzer is carried out with said output signal from said square circuit,

Circuitry which consists of a division means to generate the distortion signal corresponding to said distortion in said input signal.

[Translation done.]

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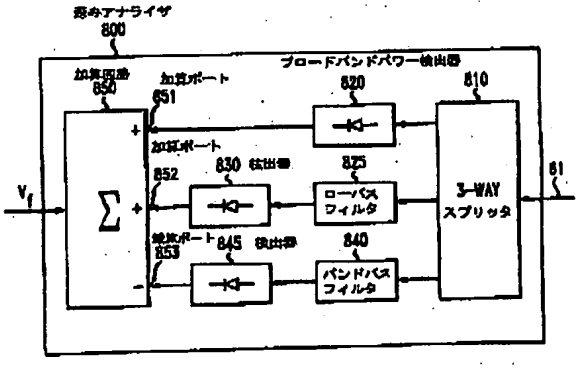
最終頁に続く

(54)【発明の名称】　光ファイバの偏光モード分散を補償する補償器

(57)【要約】
【課題】　偏光モード分散を補償する補償器を提供する。
【解決手段】　本発明によれば、光学信号が光ファイバ中を伝搬する際に受ける偏光モード分散の影響を、複屈折補償器を用いて受信器で補償する。歪みアナライザーが補償器から出力された信号を検査し、補償器がこの検査結果に基づいて偏光補償分散の影響を低減するように働く。



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【特許請求の範囲】

【請求項１】　主偏光状態を有する光ファイバ（４２０）内で発生する偏光モード分散の影響を補償する補償器（４２５）において、

（Ａ）光ファイバ（４２０）を介して受信する光学信号の特定の成分の偏光を再度方向付ける偏光変換器（４３０）と、

（Ｂ）前記偏光変換器の出力信号を、２つの主偏光状態のそれぞれの状態に直交する方向に偏光状態を有する複数の信号に分割し、この分割された信号を可変の時間遅延させる装置（４４０、４８５、４８７）と、

（Ｃ）前記（Ｂ）装置により出力された信号の一部を電気信号に変換する光学コンバータ（４５５）と、この変換された信号を複数の信号に分離（８１０）し、この分離した信号をそれぞれ第１と第２と第３のアナライザ部分（８２０、８２５、８４０）に与える装置とを有する歪みアナライザと、を有し、

前記第１アナライザ部分（８２０）は、出力信号のスペクトラム全体を通過させ、

前記第２アナライザ部分（８２５）は、所定の周波数以下のスペクトラムの一部のみを通過させ、

前記第３アナライザ部分（８４０）は、スペクトラム全体の所定の範囲のみを通過させ、

前記（Ｃ）歪みアナライザは、前記第１と第２のアナライザ部分の出力を加算（８５１，８５２）し、前記加算された値から第３アナライザ部分の出力を減算（８５３）して、歪みインジケータを生成し、この歪みインジケータ（４７１）を前記偏光変換器（４３０）と前記（Ｂ）分割装置（４４０）に与え、

前記偏光変換器と、前記（Ｂ）装置は、歪みインジケータのレベルの変化に応じて、前記歪みインジケータのレベルが所定のレベルに達するまで、前記偏光状態の方向と前記可変時間とをそれぞれ変化させることを特徴とする光ファイバの偏光モード分散を補償する補償器。

【請求項２】　前記第１アナライザ部分は、ブロードバンド電力検出器を有し、

前記第２アナライザ部分は、ブロードバンド電力検出器に直列に接続されたロウパスフィルタを有し、

前記第３アナライザ部分は、ブロードバンド電力検出器に直列に接続されたバンドパスフィルタを有することを特徴とする請求項１記載の補償器。

【請求項３】　（Ｄ１）高周波（ＡＣ）成分と低周波（ＤＣ）成分を生成するために、出力された信号の前記部分を処理する手段と、

（Ｄ２）複数の信号を生成するために、前記ＡＣ成分をスプリッタに与える手段と、

（Ｄ３）ＤＣ成分の値を二乗する信号二乗手段に、ＤＣ成分を供給する手段と、

（Ｄ４）前記減算された値を、二乗平均された信号の値でもって割算する手段と、

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（Ｄ５）この割算の商を歪みインジケータとして出力する手段を有する受信器をさらに有することを特徴とする請求項１記載の補償器。

【請求項４】　主偏光状態を有する光ファイバ内で発生する偏光モード分散の影響を補償する補償器において、

（Ａ）光ファイバを介して受信する光学信号の特定の成分の偏光を再度方向付ける偏光変換器と、

（Ｂ）前記偏光変換器の出力に与えられる信号を、２つの主偏光状態のそれぞれの状態に直交する方向に偏光状態を有する複数の信号に分割し、この分割された信号に可変の時間遅延させる装置と、

（Ｃ）前記（Ｂ）の装置により出力された信号の一部を所定の信号に変換し、この変換された信号からＡＣ成分信号とＤＣ成分信号を生成する光学コンバータを有する受信器と、

前記受信器は、ＡＣ成分信号を歪みアナライザに与え、この歪みアナライザがＡＣ成分内の少なくとも一次ＰＭＤ歪みのレベルを測定し、この歪みのレベルを表す信号を出力し、ＤＣ成分を信号二乗回路に与え、

（Ｄ）前記歪みを表す信号のレベルを、二乗された信号のレベルで割算し、その結果得られた商の信号を歪みインジケータとして偏光変換器と前記（Ｂ）装置に与える割算手段と、からなり、

前記偏光変換器と、前記（Ｂ）装置は、歪みインジケータのレベルの変化に応じて、前記歪みインジケータのレベルが所定のレベルに達するまで、前記偏光状態の方向と、前記可変時間とをそれぞれ変化させることを特徴とする光ファイバの偏光モード分散を補償する補償器。

【請求項５】　前記（Ｃ）歪みアナライザは、ＡＣ成分信号ををを複数の信号に分離（８１０）し、この分離した信号をそれぞれ第１と第２と第３のアナライザ部分（８２０、８２５、８４０）に与え、

前記第１アナライザ部分（８２０）は、出力信号のスペクトラム全体を通過させ、

前記第２アナライザ部分（８２５）は、所定の周波数以下のスペクトラムの一部のみを通過させ、

前記第３アナライザ部分（８４０）は、スペクトラム全体の所定の範囲のみを通過させ、

前記（Ｃ）歪みアナライザは、前記第１と第２のアナライザ部分の出力を加算（８５１，８５２）し、前記加算された値から第３アナライザ部分の出力を減算（８５３）して、この減算結果を前記（Ｄ）割算手段の分子として与えることを特徴とする請求項４記載の補償器。

【請求項６】　前記第１アナライザ部分は、ブロードバンド電力検出器を有し、

前記第２アナライザ部分は、ブロードバンド電力検出器に直列に接続されたロウパスフィルタを有し、

前記第３アナライザ部分は、ブロードバンド電力検出器に直列に接続されたバンドパスフィルタを有することを特徴とする請求項４記載の補償器。

【請求項７】　前記歪みアナライザは、ＡＣ成分を複数の信号に分割して、この分割された信号を第１部分と第２部分に与える装置を有し、
前記第１部分は、ブロードバンド電力検出器を有し、
前記第２部分は、ブロードバンド電力検出器に直列に接続されたローパスフィルタを有し、
前記歪みアナライザはさらに、前記第１部分と第２部分の出力を結合し、この結合された信号を計算手段に与える加算回路を有することを特徴とする請求項４記載の補償器。
【請求項８】　前記歪みインジケータは、フィードバック電圧であることを特徴とする請求項４記載の補償器。
【請求項９】　（Ａ）光学装置により出力された信号を電気信号に変換し、この変換された電気信号を複数の信号に分割するコンバータ手段と、
（Ｂ）前記複数の信号のうちのそれぞれの１つを受領する、第１と第２と第３の部分アナライザと、
前記第１部分アナライザは、出力された信号のスペクトラム全体を通過させ、
前記第２部分アナライザは、所定の周波数以下のスペクトラムの一部のみを通過させ、
前記第３部分アナライザは、スペクトラム全体の所定の範囲を通過させ、
（Ｃ）前記第１と第２の部分アナライザの出力を加算し、この加算された結果から第３部分アナライザの出力を減算して、歪みインジケータを生成し、この歪みインジケータを光学装置に与える手段と、からなることを特徴とする歪みアナライザ。
【請求項１０】　（Ａ）光学装置により出力された信号を電気信号に変換する変換手段（４５５）と、
（Ｂ）前記電気信号を、ＡＣ成分信号とＤＣ成分信号に変換して、このＡＣ成分信号を複数の信号に分割し、このＡＣ成分信号を複数の信号に分離し、そしてこのＡＣ成分信号をそれぞれの歪みアナライザの部分（１０１０）に与える受信器（１００５）と、
（Ｃ）前記ＤＣ成分信号の値を二乗する二乗手段（１０２０）と、
（Ｄ）前記歪みアナライザから出力された信号を、二乗された信号で割算をして、その結果得られた商の信号を、歪みインジケータとして光学装置に与える割算手段（１０３０）と、からなり、この歪みインジケータの受領に応じて、歪みインジケータが所定の状態に達するまで出力された信号のレベルを変化させることを特徴とする光学装置。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、光学通信システムに関し、特に、このようなシステムにおけるいわゆる偏光モード分散の処理に関する。
【０００２】
【従来の技術】偏光モード分散（Polarization Mode Dispersion：ＰＭＤ）は、小さな残留複屈折が原因で光ファイバ内で起きる。この残留複屈折は、非対称の内部応力および光ファイバにかかる外力に起因するランダムな偏光結合により、ファイバのコア内に導入されるものである。ＰＭＤは光ファイバネットワーク内の信号の伝送に悪影響を及ぼす。これは、伝送される波長チャネルにおいて、１０Ｇｂ／秒以上のビットレートで動作するような現代のデジタル光波システムについて、特に言えることである。
【０００３】米国特許第５９３０４１４号（発行日：1999.7.27 、発明者：D.A.Fishman etal, ）は、ＰＭＤに起因する信号の損傷を緩和させる装置を開示している。この装置は可変の光学複屈折要素を有し、これにより伝送ファイバ内の少なくとも２個の選択可能な相互に直交する偏光状態（すなわち主偏光状態、Principal States of Polarization：ＰＳＰ）の間に差分光学時間遅延を導入している。可変複屈折要素の出力に接続された光学歪みアナライザは、この要素に対し制御信号を生成している。
【０００４】前掲の特許の図４に示された補償装置は、伝送用ファイバ内の一次ＰＭＤを補償するために、２つの主偏光状態の間に連続的に可変の差分グループ遅延（Differential Group Delay：ＤＧＤ）を発生させている。この装置と前掲の特許の図１に示された遅延線との間の１つの異なる点は、図４に示された可変の複屈折構成要素のＰＳＰは、周波数依存性がある点である。このような周波数依存性（これはいわゆる二次ＰＭＤの影響に対し重要な側面であるが）は、光学信号に過剰の歪みを導入してしまう。その理由は、ファイバ中の一次ＰＭＤは、ある光バンド幅に対してのみ補償されるからであり、さらにまたＰＭＤは、光学スペクトラムのある部分においては依然として増加するからである。
【０００５】従来のノンリターントゥーゼロ（non-return-to-zero：ＮＲＺ）と、リターントゥーゼロ（return-to-zero：ＲＺ）のデジタル光学信号中の二次ＰＭＤの影響に起因する信号歪みは、受信光学信号の電気スペクトラム中で、ＮＲＺ信号に対しては１０ＧＨｚ、ＲＺ信号に対しては２０ＧＨｚのような信号ビットレートに対するある周波数においては、スペクトラムエネルギーのナローバンドの「トーン」として観測される。
【０００６】
【発明が解決しようとする課題】したがって本発明の目的は、ＰＭＤによる信号歪みを解除する方法と装置を提供することである。
【０００７】
【課題を解決するための手段】本発明によれば、ＰＭＤ補償装置の可変の複屈折構成要素における二次ＰＭＤの影響により引き起こされる歪みを減少させるために、可変複屈折構成要素に加えられる制御信号を、光学信号が

二次ＰＭＤの影響を最も少なく受けるように偏光することにより行われる。特に、前掲の特許の図２または８の歪みアナライザにより生成された制御信号は、制御信号から重み付けの方法により歪みアナライザにより出力されたナローバンドのトーンに合わせたバンドパスフィルタの出力信号を取り除くことにより偏光される。その結果得られた偏光された信号V_rが、可変複屈折構成要素内の偏光コントローラに加えられ、二次のＰＭＤの影響の結果として起こる歪みのレベルを低減させる。特のこの偏光したV_rによりＰＭＤの補償器は、伝送用ファイバとＰＭＤ補償器の両方の二次の歪みの全体が最小となるような点で動作することになる。本発明の特徴により、特に補償器のＰＳＰは、伝送用ファイバにより生成された二次のＰＭＤ歪みをオフセットさせる。すなわち二次の影響は、伝送用ファイバにより生成される歪みに加算されるのではなく取り除かれる。

【０００８】

【発明の実施の形態】本明細書においては、米国特許第５９３０４１４号に開示された補償システムを例に挙げて説明する。

【０００９】偏光モード分散（ＰＭＤ）は、光ファイバのコア内の残留複屈折と光ファイバに沿った様々な場所におけるランダムな偏光の結合の結果としてシングルモードファイバ中で発生する。

【００１０】光学周波数$\omega = \omega_0$に対しては、主偏光状態（ＰＳＰ）と称する２つの偏光直交状態が存在する。光ファイバを伝搬する光学信号は、それが２つのＰＳＰのうちの一方の状態で偏光している場合には、大きな差分時間差遅延を受けることはない。

【００１１】差分グループ遅延τ_rが、ファイバの２つのＰＳＰの間で発生する。光学信号が光ファイバ中を伝搬する結果として、それが被る差分グループ遅延（differential group delay：ＤＧＤ）は、光ファイバの出力点で等しい量でかつ符号が反対の差分時間遅延$\tau_0 = -\tau_r$を導入することにより補償することができる。これは、前掲の特許に開示された偏光特性を有する光学素子を用いることにより容易に行うことができる。

【００１２】ファイバ中のＰＭＤは、時間の経過と共にあるいは光学周波数が変化すると変化する。ＰＭＤ内の変化は、対応するＰＳＰの変化とＤＧＤの変化τ_rを含み、これは補償器内の複屈折の量と方向を変化させることにより補償でき、その結果ファイバ中のＤＧＤを自動的に補償する。自動可変複屈折補償器は、米国特許第５２１２７４３号（発行日：1993.5.18、発明者：F.L.Heismann, ）に開示された偏光変換器を、可変線形複屈折を生成する素子に直列に配置することにより実現できる。このような可変複屈折は、偏光変換器の出力点の信号を光ファイバの２つのＰＳＰに対応する２つの直交線形偏光状態に分離して、そのうちの一方を前掲の特許の図１の遅延線５０（例えば、JDS Fitel Inc 社から市販されている、偏光モード分散エミレータ、モデルＰＥ３）を用いて可変時間τ_rだけ遅延させることにより達成できる。

【００１３】このような複屈折を生成させる別の方法を図１に示す。この実施例は、ほぼ同一の第１光複屈折ファイバ４３５、第２光複屈折ファイバ４４５を含み、これらが２本のファイバの低速光学軸と高速光学軸に沿って直交した光学信号の間に、一定の差分時間遅延τ_1、τ_2を生成する。第１光複屈折ファイバ４３５、第２光複屈折ファイバ４４５は、Fujikura Co.，から市販されている、ＳＭ１５－Ｐ－８／１２５で、１．４ｐｓ／ｍの時間遅延を有する。したがって第１光複屈折ファイバ４３５、第２光複屈折ファイバ４４５の間に挿入された第２自動偏光変換器４４０が、第１光複屈折ファイバ４３５と第２光複屈折ファイバ４４５の高速軸の間の角度θ_2を制御する。第１光複屈折ファイバ４３５、第２光複屈折ファイバ４４５により生成された差分時間遅延τ_0は次式で表される。

【数１】

$$\tau_0 = \sqrt{\tau_1^2 + \tau_2^2 + 2\tau_1\tau_2\cos(2\theta_2)}$$

これは$|\tau_1 - \tau_2|$の最小値と$(\tau_1 + \tau_2)$の最大値の間で連続的に変化する。

【００１４】第１自動偏光変換器４３０内で行われた偏光変換と、第１光複屈折ファイバ４３５、第２光複屈折ファイバ４４５により生成された差分時間遅延と、第１自動偏光変換器４３０が前掲の特許に開示された方法により適宜調整されると、補償器４２５により出力された信号には、伝送用光ファイバ４２０内で発生する差分グループ遅延により引き起こされる歪みがなくなる。

【００１５】フィードバック信号を用いて、第１自動偏光変換器４３０内の偏光変換（すなわち可変複屈折の方向）と、第１光複屈折ファイバ４３５、第２光複屈折ファイバ４４５により生成される可変の差分時間遅延と、第２自動偏光変換器４４０を制御する。所望のフィードバック信号は、パスル歪みの量を監視することにより補償器４２５の出力点で生成される。このパルス歪みは、補償器４２５内を伝搬したあと光学信号内に存在する差分時間遅延によって引き起こされる。

【００１６】１つのフィードバック信号４７１のみが、従来の光学タップ４８５を介して補償器４２５が光学受信器４９０に出力する信号中で最小の歪みを達成するために、偏光変換と差分遅延τ_0を同時に調整するのに必要である。

【００１７】具体的に説明すると、補償器４２５が出力する信号の一部は、光学タップ４８５を介してパス４８７に与えられる。このパス４８７は、高速光検出器４５５にのびる。この高速光検出器４５５は、Hewlett Packard Co.，社のmodel 11982 Wideband Lightwave Converter で、光学送信器４１０により送信された変調光学信

号の情報バンド幅に少なくとも等しい電気的バンド幅を有する。残りの信号は、光学受信器４９０にのびるパス４８６に与えられる。高速光検出器４５５は、光学キャリア信号上に変調された高速デジタル情報信号を電気信号に変換する。この電気信号は増幅器４６０により増幅され、そして電気歪みアナライザ４７０に結合され、この電気歪みアナライザ４７０が増幅された光電流内の歪みを測定し、この増幅した結果を電気歪みアナライザ４７０へ与えられる電圧V_rに変換する。そしてこれは歪みに比例する。例えば電圧V_rは、光学信号が一次ＰＭＤに起因する歪みを有さない（すなわち伝送用光ファイバ４２０と補償器４２５の結合差分時間遅延がほぼゼロに等しい）ときに最大値に達する。

【００１８】伝送用ファイバ内のＤＧＤが最大値（τ_{max}）以下の値に制限されている場合には、光学信号内の歪みは特定の周波数$F<1/(2\tau_{max})$の受信電気信号の振幅を単に測定するだけで測ることができる。この信号の振幅をフィードバック信号として用いて、フィードバック信号が最大となるように補償器４２５内に生成されたＤＧＤの方向とレベルを自動的に調整する。

【００１９】伝送システム内に挿入される全ＤＧＤに対する上記の要件設定、すなわち$\tau_{total}<\tau_{max}$が、光学伝送用ファイバ内で補償されるＤＧＤの量τ_rを$\tau_{total}<2\tau_r$として制限する。例えば、１０Ｇｂｐｓのデジタル伝送システムおいては、受信電気信号の振幅は５ＧＨｚで測定され、τ_rは常に５０ｐｓよりも低くなければならない。さもないと、５ＧＨｚの成分の振幅の関数として生成されるフィードバック信号は、偏光変換の量と方向および差分時間遅延τ_rが$\tau_{total}=0$を得るように調整する必要があるように決定するのが困難である点で不明確となる。これは例えば、フィードバック信号の振幅がτ_{total}の２つの異なる値に対し同一の場合に発生し、そしてこれは補償器４２５内の差分時間遅延のレベルと方向を誤って調整することになる。

【００２０】「不明瞭でない」フィードバック信号（すなわちτ_{total}の唯一の測定値である信号）は、ＤＧＤに加えられる補償のレベルを制限することなく、光ファイバ内を伝搬する光学情報信号に含まれる複数の周波数成分の振幅を測定することにより生成される。ブロードバンドの電力検出器を用いて受信した電気周波数スペクトラムのほぼ全部の振幅を解析する補償器の一例が図１に示されている。ブロードバンド電力検出器４９５は例えば、Hewlett Packard Co.，社から市販されている、model 8474 ダイオード検出器であり、このような振幅を単一のフィードバック電圧V_rに変換し、そしてこのV_rは高周波電気スペクトラムの振幅（パワーレベル）の積分値に比例する。

【００２１】図１に示した補償装置は、連続的に可変の差分グループ遅延（ＤＧＤ）を生成し、一次のＤＧＤを補償する。この補償装置と前掲の特許の図１に示された

差分時間遅延線との間の異なる点は、第１光複屈折ファイバ４３５、第２光複屈折ファイバ４４５により形成された補償部分と、図１の第２自動偏光変換器４４０とが光学周波数と共に大きく変化する主偏光状態（ＰＳＰ）を示す点である。このような周波数依存性（これはいわゆる二次ＰＭＤの影響の一側面であるが）は、補償器内の光学信号を歪ませる。その理由は、ファイバ内で受けるＤＧＤは、ある光学周波数範囲においてのみ除去可能だからである。さらにまたＤＧＤは、スペクトラムのある部分では増加することさえある。

【００２２】次に従来の強度変調光学信号に対しては二次のＰＭＤの影響は、１０Ｇｂ／秒で、ノンリターントゥゼロ（ＮＲＺ）でフォーマット化されたデジタル信号に対しては約１０ＧＨｚで、１０Ｇｂ／秒のリターントゥゼロでフォーマット化された信号に対しては２０ＧＨｚの信号ビットレートの対応する周波数におけるスペクトラムエネルギーのナローバンドの「トーン」が表れることにより、電気領域で観測される。かくして、二次のＰＭＤの影響により引き起こされる歪みは、ビットレートの周波数のバンドパス特性に合わせて偏光した前掲の特許の図２、８に示す種類の電気的フィルタでもって歪みアナライザを観測することができる。

【００２３】二次ＰＭＤにより引き越される歪みの影響は、本明細書の図２の歪みアナライザにより出力された信号から、ナローバンドのトーンに同調したバンドパスフィルタの出力を、重み付けの方法により減算することにより処理できる。その結果得られた偏光された信号V_rが補償器に与えられ、二次ＰＭＤの影響の結果をして発生する歪みのレベルを低減する。さらに具体的に説明すると、偏光されたV_rにより補償器は、光学信号内の最大歪みのスペクトラム領域内の正確なＤＧＤとＰＳＰの整合の領域に中心をおく点（ディザー）に依存する。これにより二次ＰＭＤの影響を低減させることができる。本発明による改善により補償器のＰＳＰは、伝送用ファイバ内で信号が受ける二次ＰＭＤの歪みを、補償器内に生成された二次ＰＭＤが伝送用ファイバ内で受ける二次ＰＭＤの歪みに追加するのではなく、減算する方向でオフセットされる。

【００２４】図３は、本発明により偏光された歪みアナライザを示し、この歪みアナライザは増幅された電気信号を歪みアナライザに与える増幅器４６０内に変更された制御信号V_rを生成する。従来の３方向スプリッタ８１０は、増幅された信号を３つの信号に分割し、それぞれをブロードバンドパワー検出器８２０とローパスフィルタ８２５とバンドパスフィルタ８４０に与える。ブロードバンドパワー検出器８２０は、従来通り信号（信号の周波数スペクトラム全体のパワーに比例した電圧レベル）を従来の加算回路８５０の加算ポート８５１に与える。一方ローパスフィルタ８２５は、電気信号をフィルタ処理して、周波数スペクトラムの一部、すなわち２．

５ＧＨｚ以下を検出器８３０に通過させる。検出器８３０からの信号は、加算回路８５０のローパスフィルタ８２５に与えられる。さらにバンドパスフィルタ８４０は３方向スプリッタ８１０から受け取った信号をフィルタ処理して、信号の所定のスペクトラム範囲内、例えば１０ＧＨｚを中心とした１ＧＨｚの信号のみを通過させる。バンドパスフィルタ８４０から出力された信号は、検出器８４５を介して加算回路８５０の減算ポート８５３に与えられる。加算回路８５０は、従来通り加算ポート８５１と加算ポート８５２を介して受信した信号の和から減算ポート８５３を介して受信した信号を減算する。かくして歪みアナライザはフィードバック信号V_fを出力し、このV_fは信号の所定のスペクトラムの周囲、例えば１０ＧＨｚの周囲のスペクトラムをネガティブに（マイナスの方向に）協調する。このような協調により補償器、例えば図１の補償器４２５は、二次ＰＭＤの影響の結果として発生する周波数トーンと削除するために、ディザード方法で適用する。

【００２５】前掲の特許（９）式に示されたフィードバック電圧V_fと、本明細書の図３の歪みアナライザにより生成された偏光されたフィードバック電圧V_fとは、補償器４２５（例えば偏光変換器）内に生成された偏光依存性損失（polarization-dependent loss：ＰＤＬ）が存在することにより低減される。このフィードバック電圧V_fは、２段階の二乗法則（two stages of square-law detection）検出（すなわち光から無線周波数（高周波）へ、高周波から低周波へ）から取られ、そのため受信した全光学パワーの二乗に比例する。高速光検出器４５５が受信した平均光学パワーの二乗でフィードバック信号を計算することにより、補償器４２５内の偏光依存性の損失の悪影響を低下させることができ、そのためより高いレベルのＰＭＤ補償が行える。

【００２６】このような正確な制御は、本発明によれば図４に示された回路構成により行われ、この回路構成においては、周波数スプリッタ１００５が従来通り高速光検出器４５５により出力された電気信号を高周波（ＡＣ）成分と低周波（ＤＣ）成分に分割する。本発明の一実施例によれば、周波数スプリッタ１００５は、１つ、あるいは複数の従来のトランスインピーダンスＬＣ回路から形成される。高周波成分は高速デジタル信号内の歪みに関連する情報を含み、光学増幅の後歪みアナライザ１０１０に供給される（これは図２、または３の歪みアナライザのいずれかである）。低周波（ＤＣ）成分は、受信した光学パワーの平均値に比例したレベルを有し、これは従来の二乗回路１０２０に与えられる。本発明の一実施例においては、二乗回路１０２０は、互いに接続された２つの入力を有するアナログ乗算器である。二乗回路１０２０の出力点の信号がその後、従来の割算回路１０３０の分母端子（Ｄ）に与えられる。歪みアナライザ１０１０からのフィードバック電圧V_mは、割算回路１０３０の分子端子（Ｎ）に与えられる。この割算結果が割算回路１０３０の出力点にフィードバック信号V_fとして与えられる。このV_fは受信光学パワーにより正規化され、ＰＤＬに起因した光学パワー変動の影響を取り除く。

【００２７】補償器４２５内で発生する、好ましくない偏光依存型の損失の影響の低減、および自動偏光変換器の制御回路の必要とされるダイナミックレンジの低減は、本発明の利点のうちの１つである。

【００２８】上記した説明に基づき当業者は、例えば補償器４２５のような補償器を、必要に応じて高複屈折のファイバの部分と、偏光変換器をさらに含ませるようにすることによって、さらに高次のＰＭＤの影響を処理することができる。

【図面の簡単な説明】

【図１】本発明が適用される従来システムを表すブロック図。

【図２】図１のＰＭＤ補償器用にフィードバック信号を取り出すために用いられる別の歪みアナライザのブロック図。

【図３】さらに改善された歪みアナライザの他の実施例を示すブロック図。

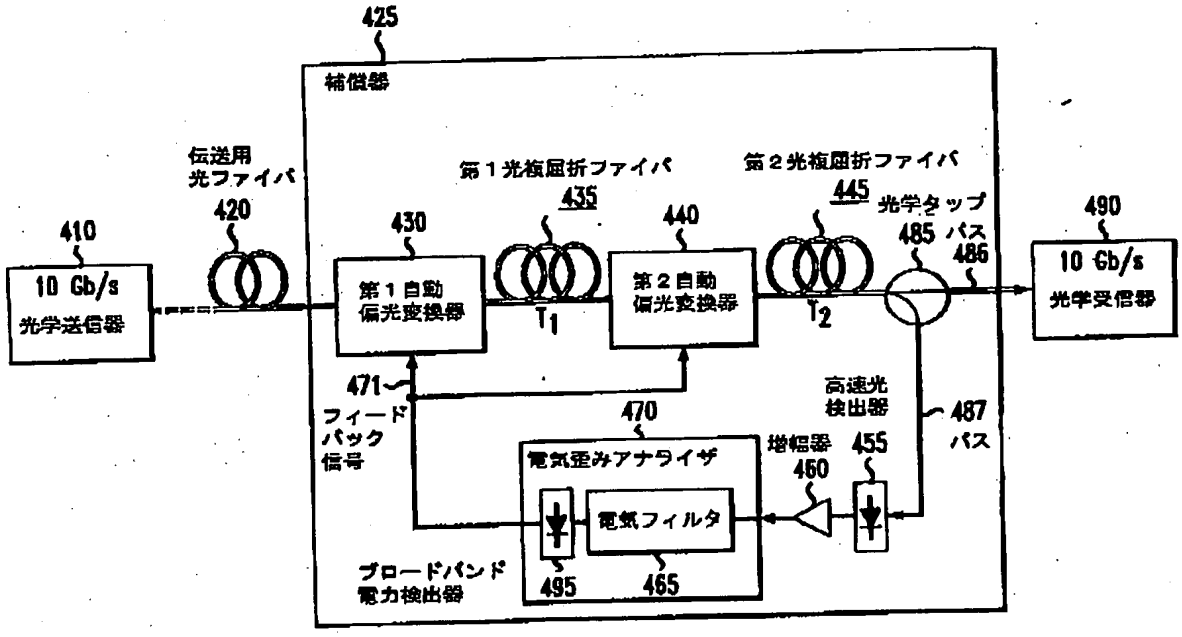
【図４】さらに改善された歪みアナライザの他の実施例を示すブロック図。

【符号の説明】

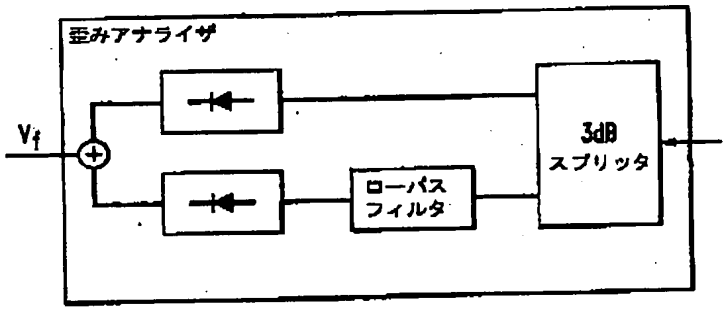
４１０　光学送信器
４２０　伝送用光ファイバ
４２５　補償器
４３０　第１自動偏光変換器
４４０　第２自動偏光変換器
４３５　第１光複屈折ファイバ
４４５　第２光複屈折ファイバ
４５５　高速光検出器
４６０　増幅器
４６５　電気フィルタ
４７０　電気歪みアナライザ
４７１　フィードバック信号
４８５　光学タップ
４８６、４８７　パス
４９０　光学受信器
４９５　ブロードバンド電力検出器
８００　歪みアナライザ
８１０　３方向スプリッタ
８２０　ブロードバンドパワー検出器
８２５　ローパスフィルタ
８３０、８４５　検出器
８４０　バンドパスフィルタ
８５０　加算回路
８５１、８５２　加算ポート
８５３　減算ポート

１００５　周波数スプリッタ
１０１０　歪みアナライザ
＊１０２０　二乗回路
＊　１０３０　割算回路

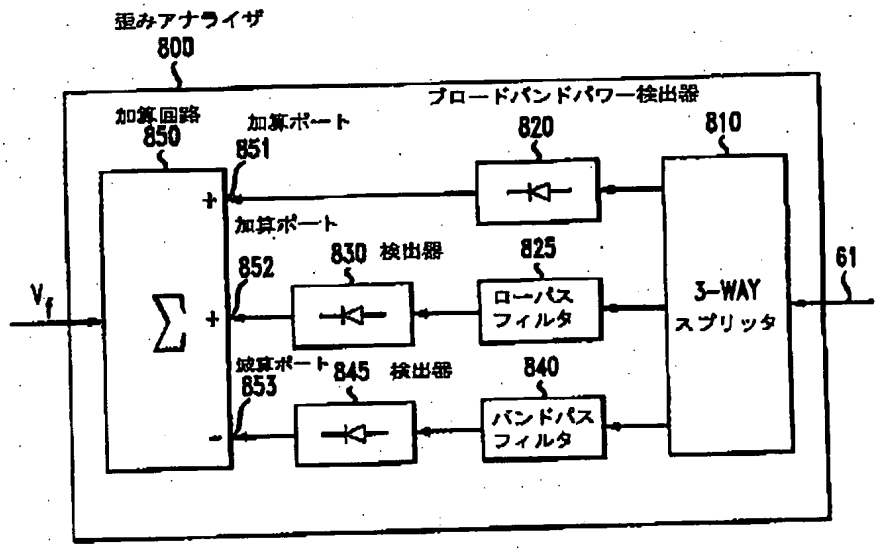
【図１】



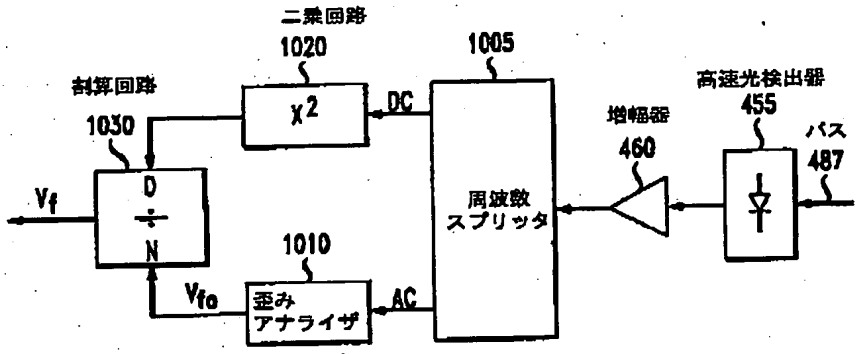
【図２】



【図３】



【図４】



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